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Human Systems IAC

GATEWAY

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USAARL Directs Diverse U.S. Army Crew Station Research Program

Clarence E. Rash

The last quarter century has seen dramatic changes in the military rotary-wing cockpit. This has been especially true for U.S. Army rotary-wing aviation. In the early 1970s, image intensification (I^2) devices, known as night vision goggles, were introduced into the Army helicopter cockpit, necessitating a major redesign of crew station lighting. In the 1980s, the fielding of the AH–64 Apache attack helicopter incorporated a novel display concept where a miniature cathode-ray-tube (CRT) and optics were integrated into the flight helmet, initiating the use of helmet-mounted displays (HMDs). A major trend in crew station design in the 1990s was the transition from the traditional dedicated instrument cockpit to the multifunction display (MFD) based "glass" cockpit. In addition, Army aviation has been striving for an all-weather, day/night, rapidly deployed operational capability. All of these factors have placed great demand on human performance and have introduced numerous human factors engineering (HFE) issues.

The U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, formally established in 1962, has continued to direct a diverse research program in support of the rotary-wing cockpit, conducting a wide range of projects and studies that address human performance and HFE issues associated with the changes in Army aviation.

A number of studies have focused on visual performance with various

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14. ABSTRACT

This newsletter contains information on multifunction displays, visual syptoms related to helmet-mounted displays, Human Error on Crew station changes, and Developing Crew Rest. It also has a calendar of upcoming human factors events.

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optical components and systems that are required to be worn in front of the aviator's eyes. These include simple optical devices such as standard spectacles, laser protective devices, protective gas masks, and visors, as well as currently fielded, sophisticated display systems such as night vision goggles and the monocular AH–64 Apache HMD. Recently, a series of studies has been conducted to investigate visual detection thresholds and visual artifacts associated with partial-overlapped HMD designs under consideration for the Army's RAH–66 Comanche helicopter (Gateway, Vol. VI, Number 4 (1995)). A current study is investigating binocular alignment optical tolerances and analogous misalignment effects on visual performances with proposed binocular HMD designs.

The current and future use of HMDs in Army cockpits has generated a number of studies addressing human factors engineering and safety issues associated with these systems. Current studies include an investigation of the incompatibility of corrective vision devices (e.g., spectacles), protective gas masks, laser protective devices, and oxygen masks with the limited eye relief distance provided by HMD optical designs. In another study, a spatial-temporal model was developed for predicting available number of shades of gray in the pilotage imagery provided to the aviator's eye(s) for a selected combination of background scene and ambient lighting condition, cockpit lighting, sun and/or laser protective visors, HMD image source spectra, aircraft windscreen, and HMD design.

Another series of studies has investigated physiological performance when the cockpit environment is driven to high temperature extremes, such as in the desert environment, and the aviator is required to wear some type cooling system, e.g., microclimate cooling vests. Simulator flight performance under environmental conditions of 95°F and 105°F, both at 50 percent relative humidity (RH), has been studied using both water-cooled and forced-air-cooled microclimate vests.

The recent emphasis on rapid deployment, crossing multiple time zones, and still being ready to fly an aircraft with limited crew rest, has motivated several studies investigating the effectiveness of pharmaceutical intervention to enhance alertness or optimize crew rest. The stimulant modafinil has been evaluated for its ability to sustain simulator flight performance, cognitive skill, psychological mood, and central nervous system (CNS) activation in helicopter pilots who had been deprived of sleep for periods up to 40 hours. Similarly, the hypnotic temazepam has been evaluated for its usefulness in ensuring that personnel obtain as much rest and sleep as possible during the time required to adjust to reverse cycle so they may perform their duties effectively.

In the following articles, selected projects on glass cockpit accident rates, optimizing the presentation of hierarchical information on MFDs, visual symptoms associated with the AH–64 Apache HMD, and crew rest strategies are described.

Technical reports on the research projects past and present are available and can be downloaded at the USAARL web site, http://www.usaarl.army.mil.

All the views, opinions, and/or findings contained in the following articles are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items. ■

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A Software Tool To Optimize Information On Multifunction Displays

Gregory Francis
Clarence E. Rash

Display clutter has been a classic problem in the cockpit, where available space is limited and information volume and need are great. One solution to this problem is the use of multifunction displays (MFDs). MFDs are capable of presenting a variety of information from diverse sources, thereby freeing up space in the cockpit. They increase the total amount of information available, but with the limitation that only some of it can be presented at any given time. The information presented on an MFD is generally arranged hierarchically so that the user starts at a top level and moves down the hierarchy by selecting appropriate MFD pages. Other uses of MFDs include automated teller machines, medical devices, electric typewriters, retail registers, and fax machines.

Designing an MFD is a challenging task. The human-computer interactions involved in accessing information from an MFD are complicated and not entirely understood. At some point in the design of an MFD, decisions must be made about how to map the various parts of the information hierarchy to user actions (e.g., button pushes). This subtask is difficult because the ability to map even a small hierarchy database to hardware buttons leads to a combinatorial explosion that precludes an exhaustive search of all possible mappings. Therefore, MFD designers generally rely on experience and guidelines. Francis and Reardon (1997) summarized many of these guidelines, which, while helpful, are of limited utility because the complexity of the task makes it difficult to insure that a set of guidelines is being followed. These decisions can affect user performance in tasks related to aircraft flight (Reising & Curry, 1987).

The U.S. Army Aeromedical Research Laboratory has sponsored development of an MFD design tool, MFDTool, which aids the designer in optimizing the assignment of MFD information to MFD hardware/software commands (e.g., button pushes). MFDTool is computer software that accepts designer-defined constraints, builds an MFD hierarchy, and then associates the hierarchical information with physical buttons on specified MFD hardware.

MFDTool provides a graphical interface for an MFD designer to build an MFD hierarchy and to associate the hierarchical information with physical buttons on specified MFD hardware. Through the graphical interface, the designer creates a variety of constraints on the MFD labels, and the program identifies the best MFD design that satisfies the constraints. The designer also defines types of human-computer interactions by identifying the "difficulty" of going from one button to another. Difficulty is a very general term that can correspond to perceptual resolution, focus of attention, time to move between buttons, or any other factor the designer believes is important.

For example, a designer may want to minimize the average time it takes a user to physically move between buttons. The interaction could be defined by a computation of the time required to move between pairs of buttons. The designer would then identify the proportion of times each label is needed by the user and create a constraint to minimize the average movement time. MFDTool then performs an optimization that will place the most frequently used labels on buttons so that there is little movement between buttons, thereby minimizing movement time.

A designer could also add additional constraints. For example, perhaps a *Cancel* label is on every page, and the designer wants that label to be in the same place on every page. This constraint can be added to the earlier design, and MFDTool now tries to minimize movement time, but with the restriction that the *Cancel* label is associated with the same button on each page. Likewise, a designer might wish to associate the *Cancel* buttons only on either of the bottom two buttons. The

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designer simply adds such a constraint and MFDTool performs the optimization subject to all the constraints.

Other types of interactions can also be defined. For example, in military aircraft, a pilot often has multiple methods of interacting with an MFD. One method is the traditional bezel buttons located around the MFD screen. In many cases, additional commands can also be generated with hand-on-throttle selections that cycle through the various options. An optimal MFD design for one interaction type might be poor for another. Given the proper constraints and identification of the frequency of use for each interaction type, MFDTool can then optimize the overall design to best accommodate *both* types of interactions. Likewise, a designer can specify interaction types that may be user specific (e.g., pilot and co-pilot) and identify the overall best MFD design to work with all of these interactions and needs.

MFDTool also provides for manual creation of MFD designs, thereby allowing a designer to consider what would happen if a button was added, deleted, moved, enlarged, etc., or if the hierarchical arrangement of information was modified.

MFDTool is written in the Java programming language. A full description of MFDTool, source code, and the procedures to use it, is provided in Francis (1999). The most recent executable code and a user's guide are available at http://www.psych.purdue.edu/~gfrancis/MFDTool/. ■

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Francis, G. & Reardon, M. (1997). *Aircraft multifunction display and control systems: A new quantitative human factors design method for organizing functions and display contents*. (USAARL Report No. 97–18). U.S. Army Aeromedical Research Laboratory: Fort Rucker, AL.

Reising, J. & Curry, D. (1987). A comparison of voice and multifunction controls: Logic design is the key. *Ergonomics, 30*, 1063–1077.

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Web-Based Survey of Helmet-Mounted Display Visual Symptoms Reported by Apache Aviators

Clarence E. Rash
Christie L. Suggs

The AH–64 Apache, which incorporates forward-looking infrared (FLIR) sensors and the integrated helmet and display sighting system (IHADSS) helmet-mounted display (HMD) (Figure 1), is an aircraft which lends tremendous capability to the Army's doctrine of night and foul weather operation. The AH–64 has proven its operational effectiveness over its near two-decade fielding, which provides evidence to its operational effectiveness. As aviators have gained experience with the use of the monocular HMD, complaints of visual problems have surfaced. In late 2000, the U.S. Army Aeromedical Research Laboratory (USAARL) asked Apache pilots to complete a web-based survey that asked about their experience with the AH–64 Apache's HMD. A total of 216 aviators (approximately 12 percent of the AH–64 pilot population) responded to the survey. See Table 1 for the survey demographics.

Figure 1. The AH–64 Apache IHADSS

	Mean	Range
Age (years)	36.5	23–53
Total flight hours	2,131	220–9,500
AH–64 flight hours	1,116	20–5,000

Table 1. Survey Demographics (n=216)

Prolonged flight with HMDs, coupled with the unique characteristics of the monocular IHADSS, can result in increased visual workload. This may result in visual discomfort, headaches, blurred or double vision, and afterimages. These symptoms can occur both *during* and *after* flight.

The major purpose of this study was to investigate aviator visual complaints with the use of the AH–64 Apache IHADSS monocular HMD. Approximately 92 percent of the aviators reported experiencing at least one visual symptom either *during* or *after* flight. The mean number of reported symptoms was 2.5 and 2.4 *during* and *after* flight, respectively. The most common visual symptom reported *during* flight was visual discomfort (81.5 percent); this same symptom was the most frequently reported as having been experienced *after* flight (74.1 percent). Similarly, the second most reported symptom for both *during* and *after* flight, was headache. See Table 2 (page 6) for the reported visual symptoms.

An important issue for monocular HMDs is eye dominance, which refers to the preference an individual exhibits to accepting visual input in one eye over the other. In this survey, the distribution of eye preference was 84.3 percent for the right eye and 15.7 percent for the left eye. When eye preference was compared to the frequency of visual complaints, it was found that respondents reporting a right eye preference averaged 2.5 visual complaints *during* flight and 2.4 complaints *after* flight. The mean numbers of complaints for the left eye were identical. Based on these findings, there is no reason to assume eye preference played a role in the visual complaints.

During flight, Apache aviators using the FLIR sensor imagery to fly the aircraft are presented with two disparate views—sensor imagery in the one (right eye) via the helmet display unit (HDU)

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	During Flight			After Flight		
	Never	Sometimes	Always	Never	Sometimes	Always
Visual discomfort	18.5	76.4	5.1	25.5	66.2	7.9
Headache	38.9	59.7	0.9	36.1	61.1	1.4
Double vision	93.5	6.0	0.5	93.1	4.6	0.5
Disorientation	57.4	42.1	0.0	88.4	9.7	0.0
Afterimages	70.4	27.3	1.9	51.9	41.7	5.1

Table 2. Reported Visual Symptoms

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and view of the cockpit/outside scene via the other (left) unaided eye. Almost two-thirds (64.4 percent) reported unintentional alternation during flight. Most aviators (74.5 percent) reported being able to switch their attention with ease. Almost half (44.9 percent) reported having developed a strategy to aid in switching. Such strategies included closing one eye, glancing away, or blinking both eyes.

Static and dynamic illusions, such as poor distance estimation and perception of false motion, also can occur. Approximately 92 percent and 95 percent of the respondents reported at least one static or dynamic illusion, respectively. Of the seven types of static illusions reported, five were reported by more than half of the respondents. The most reported static illusion was faulty slope estimation (80.1 percent), followed by faulty height judgment (73.6 percent).

A high incidence of dynamic illusions was also reported. Of the eight symptoms, six were reported by more than half of the respondents, with undetected drift (78.2 percent) and faulty closure judgment (75.5 percent) being the most reported. Illusory drift was the third highest reported in the current survey (71.3 percent).

While the responses to the structured questions in the survey were of great importance in addressing the visual issues associated with the use of the IHADSS HMD, almost half (46.3 percent) of the respondents took the opportunity to expand on previous responses or provide additional insight into HMD flight with the IHADSS via a final comment section.

Several aviators expressed the belief that their right eye vision had "gotten worse...due to use of the IHADSS." However, an almost equal number expressed the opposite belief that vision in their left eye had "gotten worse over the past 2–3 years." The survey question that asked aviators if their better (preferred) eye was the same [now] as prior to AH–64 training, had a response of almost two-thirds (63.4 percent) answering in the affirmative. However, the remaining third (35.6 percent), who felt vision in their better eye had changed, is still a substantial proportion.

Some of the most vehement comments addressed the quality of the imagery provided by the FLIR. This nose-mounted sensor provides the visual input used by the pilot to fly the aircraft at night and during inclement weather. Of the 100 aviators providing responses to the request for additional comments, the most frequent subject of these comments was FLIR image quality. The general tone of the comments was extremely negative towards the use of 30-year old sensor technology on the Army's most advanced attack helicopter. Care must be taken to disassociate the quality of the FLIR input video signal from the performance of the IHADSS, which serves as the display for the FLIR imagery. According to the Apache Program Manager, advanced generation FLIR upgrades are programmed for the near future.

While a few aviators expressed a desire for a "lighter-weight, binocular system with greater field-of-view," most of the comments in a category of monocular versus binocular design indicated a preference for a monocular display or at least the capability of using the supplied HMD in a monocular mode. The most common argument for a monocular design was the frequent advantage of having one "dark-adapted eye" during night flights.

The major conclusions that can be drawn from the survey are:

- There was sufficient data to indicate that aviators flying with the IHADSS experience a relatively high frequency of a variety of visual symptoms; 92 percent of respondents reported at least one visual complaint/symptom either *during* or *after* flight.

- The frequency of complaints was not correlated to age or AH–64 flight experience.
- The data did not support any association between eye preference (dominant eye) and the number of complaints or the presence of unintentional alternation (switching) between the left, unaided eye and the right, aided eye viewing the IHADSS imagery.
- The two most reported static illusions were faulty slope estimation and faulty height judgment; these illusions were reported by approximately three-quarters of the respondents. There was a high incidence of dynamic illusions reported. The two most reported dynamic illusions were undetected drift and faulty closure judgment; these illusions were reported by more than three-quarters of the respondents.

Visit the Technical Reports section of the USAARL web site http://www.usaarl.army.mil to download the full report, Report No. 2002–02. ■

calendar

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MIT, Cambridge, MA, USA. October 23–25, 2002
HCI-Aero Human-Computer Interaction in Aeronautics
Contact: HCI-Aero 2002 Office, European Institute of Cognitive Sciences and Engineering (EURISCO), 4 Avenue Edouard Belin, 31400 Toulouse, France. Tel: +33 (0) 5 62 17 38 38, Fax: +33 (0) 5 62 17 38 39, E-mail: hci-aero2002@onecert.fr, URL: http://www-eurisco.onecert.fr/events/hci-aero2002.html

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Alexandria, VA, USA. November 4–7, 2002
Department of Defense Human Factors Engineering Technical Advisory Group
Contact: Sheryl Cosing, 10822 Crippen Vale Court, Reston, VA 20194, USA. Tel: +1–703–925–9791, Fax: +1–703–925–9694, E-mail: sherylcosing@earthlink.net, URL: http://dtica.dtic.mil/hftag

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Orlando, FL, USA. December 2–5, 2002
I/ITSEC Interservice/Industry Training, Simulation, and Education Conference
Orange County Convention Center on International Drive
URL: http://www.iitsec.irg/poc.htm

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Dallas, TX, USA. March 10, 2003
6th Annual Applied Ergonomics Conference
Contact: Institute of Industrial Engineers, 3577 Parkway Lane, Suite 200, Norcross, GA 30092, USA. Tel: +1–800–494–0460, +1–770–449–0460, Fax: +1–770–441–3295
URL: http://www.appliedergo.org

Los Angeles, CA, USA. March 22–26, 2003
Virtual Reality Conference 2003
URL: http://www.vr2003.org/main.html

apr

Augusta, GA, USA. Spring 2003
Department of Defense Human Factors Engineering Technical Advisory Group
Contact: Sheryl Cosing, 10822 Crippen Vale Court, Reston, VA 20194, USA. Tel: +1–703–925–9791, Fax: +1–703–925–9694, E-mail: sherylcosing@earthlink.net, URL: http://dtica.dtic.mil/hftag

Fort Lauderdale, FA, USA. April 5–10, 2003
The CHI 2003 Conference on Human Factors in Computing Systems
Contact: Gilbert Cockton and Panu Korhonen, CHI 2003 General Conference Co-Chairs, E-mail: chi2003-chairs@acm.org, URL: http://www.chi2003.org

Newport News/Williamsburg, VA, USA. April 7–27, 2003
Aviation World's Fair
URL: http://www.aviation-worlds-fair.com

Bamberg, Germany. April 10–12, 2003
Fifth International Conference on Cognitive Modeling
E-mail: iccm2003@gmx.net, URL: http://iccm2003.ppp.uni-bamberg.de

Durham, NH, USA. April 22, 2003
13th Ergonomics Conference
Contact: Walter Charnizon, President, Continental Exhibitions, 370 Lexington Avenue, New York, NY 10017, USA. Tel: +1–212–370–5005, Fax: +1–212–370–5699, URL: http://www.ergoexpo.com/NECEhome.html

# of events

San Antonio, TX, USA. May 4–9, 2003
74th Annual Scientific Meeting of the Aerospace Medical Association
Contact: Aerospace Medical Association, 320 South Henry Street, Alexandria, VA 22314–3579, USA. Tel: +1–703–739–2240, Fax: +1–703–739–9652, URL: http://www.asma.org

may

Johnstown, PA, USA. June 22–26, 2003
9th International Conference on User Modeling
Contact: Peter Brusilovsky, School of Information Sciences, University of Pittsburgh, 135 North Bellefield Avenue, Pittsburgh, PA 15260, USA. Tel: +1–412–624–9404, E-mail: peterb@pitt.edu, URL: http://www2.sis.pitt.edu/~um2003

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Crete, Greece. June 22–27, 2003
HCI International 2003
10th International Conference on Human-Computer Interaction jointly with Symposium on Human Interface (Japan) 2003, 5th International Conference on Engineering Psychology and Cognitive Ergonomics, and 2nd International Conference on Universal Access in Human-Computer Interaction
Contact: Maria Papadopoulou, ICS-FORTH, E-mail: administrator@hcii2003.gr, URL: http://www.hcii2003.gr

Seoul, South Korea. August 24–29, 2003
The XVth Triennial Congress of the International Ergonomics Association
URL: http://www.iea2003.org

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Denver, CO, USA. October 13–17, 2003
Human Factors and Ergonomics Society 47th Annual Meeting
Contact: Human Factors and Ergonomics Society, P.O. Box 1369, Santa Monica, CA 90406–1369, USA. Tel: +1–310–394–1811, Fax: +1–310–394–2410, E-mail: info@hfes.org, URL: http://www.hfes.org

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Memphis, TN, USA. November 2–4, 2002
The Second International Conference on Mobile Health
Contact: International Mobile Health Association, 1058 Haight Street, San Francisco, CA 94117–3109, USA. URL: http://www.intlmobilehealthassn.org

nov

Las Vegas, NV, USA. December 9–12, 2003
National Ergonomics Conference and Exposition
Contact: Walter Charnizon, President, Continental Exhibitions, 370 Lexington Avenue, New York, NY 10017, USA. Tel: +1–212–370–5005, Fax: +1–212–370–5699, URL: http://www.ergoexpo.com/NECEhome.html

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U.S. Army Rotary-Wing Crew Station Changes: Impact on Human Error?

Gina Adam

The U.S. Army Safety Center (USASC) maintains a database of accident reports for all Army vehicles, including all aircraft types in the Army inventory. This database is a tool to determine the success of the Army's risk management efforts and also provides researchers a means to analyze human factors concerns in Army aviation generally, and in particular, aircraft.

An emerging concern in the U.S. Army aeromedical community is that of the impact of additional technology and automation in rotary-wing cockpits. Traditional cockpits include numerous analog gauges, each indicating a predetermined piece of flight information (e.g., altitude, airspeed). Cockpits are changing with the addition of multifunction displays (MFDs) that depict flight and mission information on computer screens that can change with the push of a button. The use of these MFDs as the primary flight displays while eliminating most standard instruments has introduced the term "glass cockpit." In the evolution of these crew stations, there are some hybrid cockpit aircraft with a mixture of traditional instruments and MFDs.

A previous investigation of accident rates for U.S. Army rotary-wing aircraft was conducted for four aircraft types with either traditional, glass, or hybrid cockpits (Rash et al., 2001). This report indicated trends for greater accident rates for glass cockpit aircraft compared to those with traditional cockpits. However, the review also indicated that there are many potential factors related to the accident rates (e.g., other aircraft changes, mission differences). Additionally, there were fewer accidents in the glass cockpit aircraft and much lower flight hours than with traditional cockpit aircraft, because aircraft with MFDs have only recently been fielded. Thus, no firm conclusions can be drawn regarding the effect of increased digitization in the cockpit by looking at accident rates alone.

The above report provided a thorough overview of accident rates for the included aircraft, but it did not provide any detail about the types of accidents that had occurred. A more qualitative review of the existing accident reports was conducted to investigate the effects that glass cockpits have on aviator performance. There are many possible human errors (crew coordination failures, situation awareness lapses, mishandling of workload), and it may be that cockpits with their detailed MFDs increase the potential for human error. Thus, a review of accident classifications and causative factors was undertaken to assess the role of human error in traditional, hybrid, and glass cockpit rotary-wing aircraft.

The current investigation of human error as a cause of aviation accidents includes four rotary-wing aircraft and considers only the years during which two or more cockpit types in each aircraft were in use through the end of fiscal year (FY) 2001. The aircraft included were OH–58A–C/D (Kiowa/Kiowa Warrior) with traditional (beginning 1968) or glass cockpits (beginning in FY 1985) CH/MH–47 models (Chinook) with traditional (beginning 1962), hybrid (beginning 1990), or glass cockpits (beginning in 1996) and EH/UH/MH–60 models (Blackhawk) with traditional (beginning 1978), hybrid (beginning 1990), or glass cockpits (beginning in 1996) and AH–64A/D (Apache/Longbow) traditional (beginning 1986) and glass cockpits (starting with 1997).

The USASC database lists all aviation accidents in the categories of flight, flight-related, and aircraft-ground and classifies them according to their severity. The data reported here includes all aviation accidents from the three most severe classes (see Table 1, page 11).

Of the accidents included here, the overwhelming majority of them were flight accidents (55 percent to 93 percent per aircraft). Additionally, class C accidents are most heavily represented in this data (44 percent to 82 percent per aircraft). The contribution of human error, materiel failure, and environmental factors is

Accident Class	Cost	Injury
Class A	Greater than $1,000,000	Fatality or permanent total disability
Class B	$200,000 to $1,000,000	Permanent partial disability
Class C	$10,000 to $200,000	Nonfatal injury/illness

Table 1. Aviation Accident Data From the Three Most Severe Cases

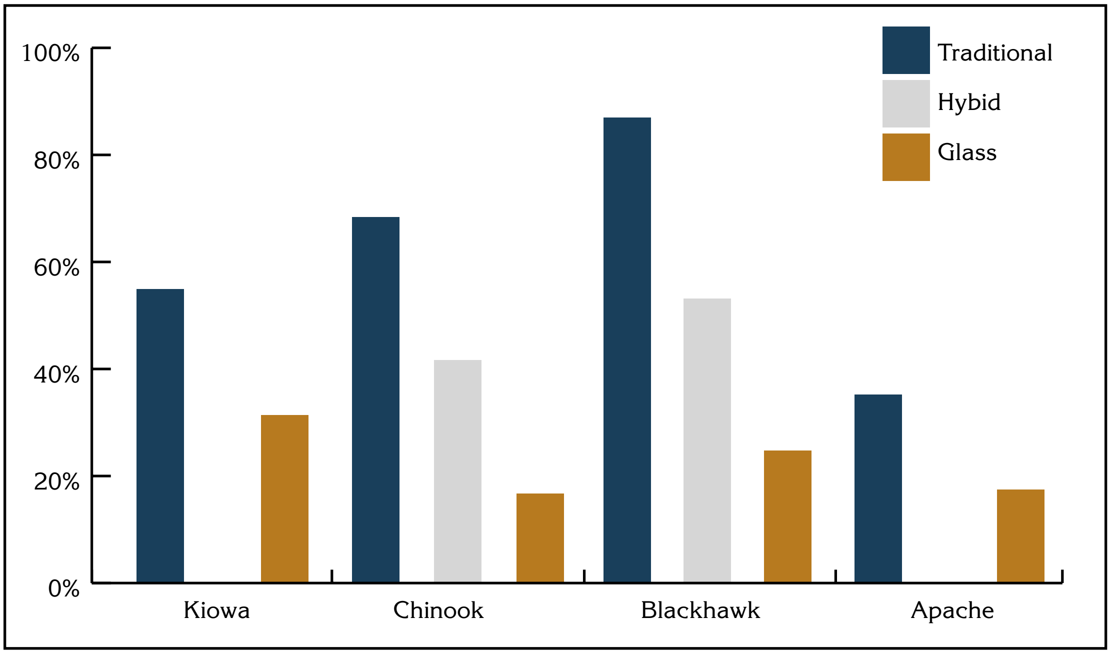

Figure 1. Definite Human Error As Accident Cause

assessed for each accident at the time of its initial report with each factor classified as definite, suspected, unknown, or no contribution. Additionally, each initial accident report is assigned up to three event codes to quickly identify the scope of the accident.

One of the initial findings of this investigation is that human error was named as a definite cause in 40 to 80 percent of the included accidents (see Figure 1). Although statistical comparisons cannot be performed with these data due to the vastly different numbers of accidents and flight hours, it is interesting to note that the two aircraft with hybrid cockpits averaged a larger percentage of accidents due to human error as cockpit technology increased. However, the Apache models show equivalent human error levels, whereas the Kiowa shows a decrease in accidents due to human error with the glass cockpit as compared to the traditional cockpit.

Before taking either trend at face value, it is important to note that there are special circumstances surrounding each aircraft. First, all aircraft except the Kiowa have been flying with MFDs for 10 years or less and thus have low numbers of accidents in their glass cockpit models (Chinook, 9; Blackhawk, 13; Apache, 9). Additionally, the Chinook and Blackhawk hybrid and glass cockpit models are currently in use only in the Special Operations community, which clearly has a different mission and intensity than the greater Army aviation community. These concerns may lead some to point to the Kiowa Warrior as an example of decreased accidents being related to human error with the glass cockpit. Unfortunately, this conclusion may be premature as the Kiowa aircraft, especially the glass cockpit model, is plagued by other design deficiencies that may significantly affect its accident rate (Simmons, 2001).

An additional means of examining human error in these accidents was to look at the reported events that contributed to each accident. First, there is a general human factor event code that was identified as a contributor in 56 percent, 38 percent, and

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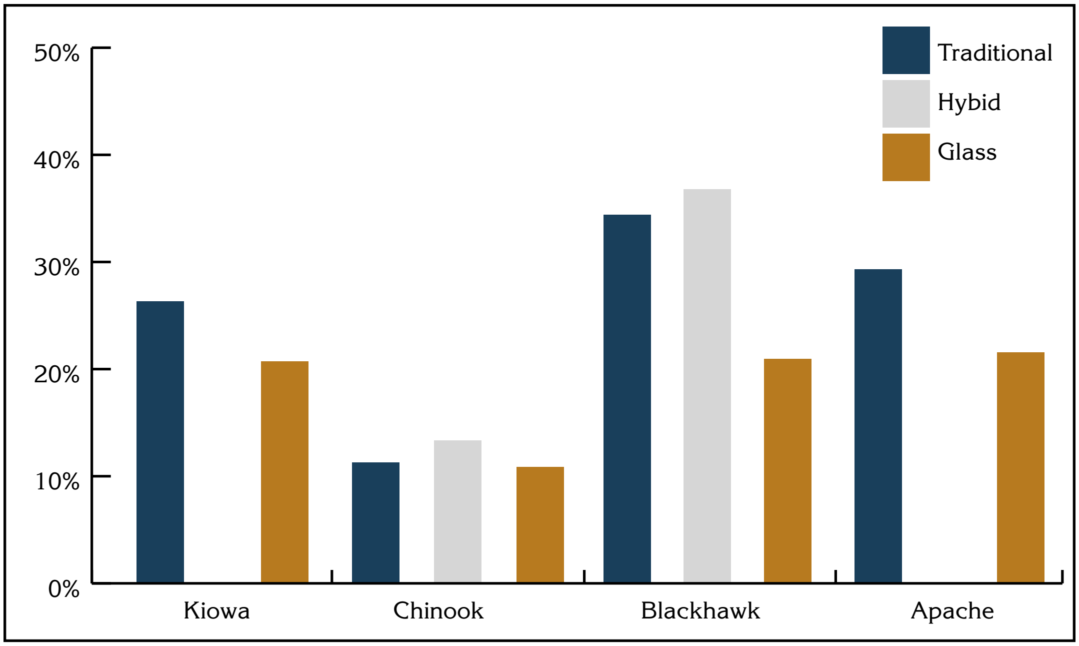

Figure 2. Strike Events As Accident Contributing Factor

8 percent of Chinook glass, hybrid, and traditional cockpit accidents, respectively. This code was identified much less frequently for all other aircraft (from 1 percent in Apache accidents to 13 percent for Blackhawk hybrid cockpit accidents). Clearly, human error is easily identified as a contributor to Chinook accidents, which coincides with the fact that the Chinook experienced the highest percentage of flight related and ground accidents of these aircraft. In fact, the Chinook is used extensively in transport operations which require significant work with greater numbers of personnel involved.

In addition to the identified human factor event, several other event codes are primarily the result of human error. For example, striking objects while in flight is a significant hazard (i.e., tree strike, wire strike, object strike) and implies that pilots were unaware of or misjudged their location with respect to obstacles. In fact, strike events were contributory factors in over 30 percent of accidents with both traditional and hybrid Blackhawk cockpits (see Figure 2). Additionally, when examining drift [any unintentional motion of the aircraft from a hover position] accidents for the OH–58 in the past five years, Leduc et al. (2002) found that there were significantly greater flight accidents caused by drift with the glass cockpit model Kiowa Warrior as compared to the traditional cockpit Kiowa.

The data presented here show that human error is a significant contributor to U.S. Army aviation accidents. However, what is not yet clear is how the addition of technology to the cockpits is affecting aviator performance. Further work is currently in progress to identify the types of human errors involved in rotary-wing accidents for aircraft with these different crew stations. Specifically, factors such as divided attention and increased workload due to management of computerized cockpit interfaces are being investigated (Adam and Noback, in preparation). Additionally, there is other research ongoing to identify how aviator workload is affected by the introduction of MFDs with the goal of providing strategies to minimize task overload in U.S. Army rotary-wing cockpits. ■

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Developing Crew Rest

J. Lynn Caldwell, Ph.D.

The issue of working reverse cycle in aviation is a complicated one. While aviators may be restricted by crew rest guidelines in how many hours they may fly, there is no restriction on *when* these hours may be flown. Many times aviators and other air crew are required to fly or work at various times in the 24-hour day where they may need to reverse their work hours from typical day times to nights, early mornings, or late evenings. When this rotation occurs, aviators or crew members become "shift workers" in that they no longer work set hours, but must change their work hours every week, every two to three days, or possibly even on a daily basis, whether for the short-term or the long-term. When this happens, all the physiological symptoms typically experienced in shift work occur: fatigue, sleepiness, insomnia, moodiness, etc. Along with these symptoms come performance problems and mistakes that can have disastrous consequences when flying.

Previously a survey was conducted by the U.S. Army Aeromedical Research Laboratory (USAARL) to determine how frequently and what hours Army aviation personnel worked night shift (or reverse cycle) (USAARL Report No. 99–16). A total of 157 aviation personnel from three Army posts were sampled using a one-page questionnaire. One survey finding was that the majority (96 percent) of aviation personnel had experienced working night shift/reverse cycle at some point in their careers. Additionally the survey revealed that although most respondents were able to sleep after a night shift for at least seven hours, many of them indicated they did not feel they received adequate daytime sleep most or some of the time. The results of this survey led to a laboratory study in which a simulated night shift was worked and a pharmacological countermeasure (temazepam) was tested in order to help alleviate some of the fatigue-related problems associated with reverse cycle (USAARL Report No. 2002–05). This study showed temazepam to be successful in improving daytime sleep. Subjects in the temazepam group slept longer and with less fragmentation than those subjects in the control group.

The feelings of fatigue that people have when they rearrange their schedule (trying to stay awake at night and then sleeping during the day) are not unique. Almost everyone who works varying schedules feels sleepy and tired during the night when they need to be alert and working. In addition, they experience difficulty sleeping during the day when trying to recoup from a night of work. This is a normal feeling because night activity and day sleep are in opposition to the body's natural programming.

The rhythms of wake and sleep, hormonal secretions, performance, and core body temperature rise and fall in predictable patterns over the 24-hour day. Alertness levels follow the body temperature curve closely, with melatonin levels being a mirror image of core body temperature. The figure demonstrates that as alertness decreases into the night, melatonin levels increase and temperature decreases. As the day begins, body temperature, alertness, and performance are rising while melatonin levels decrease. This continues into the day, with a slight dip in the midafternoon, and then begins to fall as the day ends and night begins. In contrast, sleepiness declines as the day begins, has a small increase in the midafternoon, and then steadily increases as the day ends and night begins. The ability to go to sleep and stay asleep becomes increasingly difficult as the day progresses. One can readily determine why it is so difficult for shift workers to remain awake while on night shift and sleep during daylight hours.

A host of activities are affected when an individual experiences a constant change in schedules. These activities include work, safety, health, family and social life. So, what can the aviator or

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crewmember who works shifts do to make life easier and minimize feelings of irritability and tiredness?

- Avoid caffeine four to six hours before bedtime.
- Avoid sunlight after a night shift by wearing dark sunglasses while driving home.
- Stay indoors and avoid sunlight as much as possible until your sleep period is complete.
- Relax before sleep time; avoid activities which are stimulating such as house and yard work.
- Avoid alcohol for at least three hours before bedtime.
- Get a minimum of six hours of sleep; take naps if you cannot get enough sleep at one time.

The above strategies are very good at promoting sleep. However, other strategies may be needed to stay asleep.

- Sleep in your regular bedclothes and in your usual bed.
- Have a comfortable mattress and pillow.
- Make the bedroom cool and very dark.
- Remove the phone from the room and discourage daytime visitors.
- Disconnect the doorbell and hang a sign indicating a shift worker is sleeping.
- Use earplugs and a masking noise like a fan to cover outside distractions.
- Develop a sleep schedule.
- Communicate with family and friends your need to sleep and your sleep schedule.

Although sleeping as well as possible during the day is a great start to being alert during the night, nighttime sleepiness will continue to occur. One cannot completely trick the body into being alert during the night because there is a strong physiological drive for sleep during these hours. The body can adjust somewhat to the night schedules; however, most shift workers are off of the night shift by the time this occurs. Nevertheless, there are some strategies that can improve alertness at night.

- Use caffeine carefully; wait until you need a boost.
- Eat low carbohydrate, low fat, and high protein foods.
- Use social interactions and physical activity/postural changes to help stimulate your environment.
- Stay cooler than usual.
- Prepare in advance for changes in sleep schedules by gradually adjusting your sleep time.
- Use naps to obtain as much sleep as possible before the night's work begins.

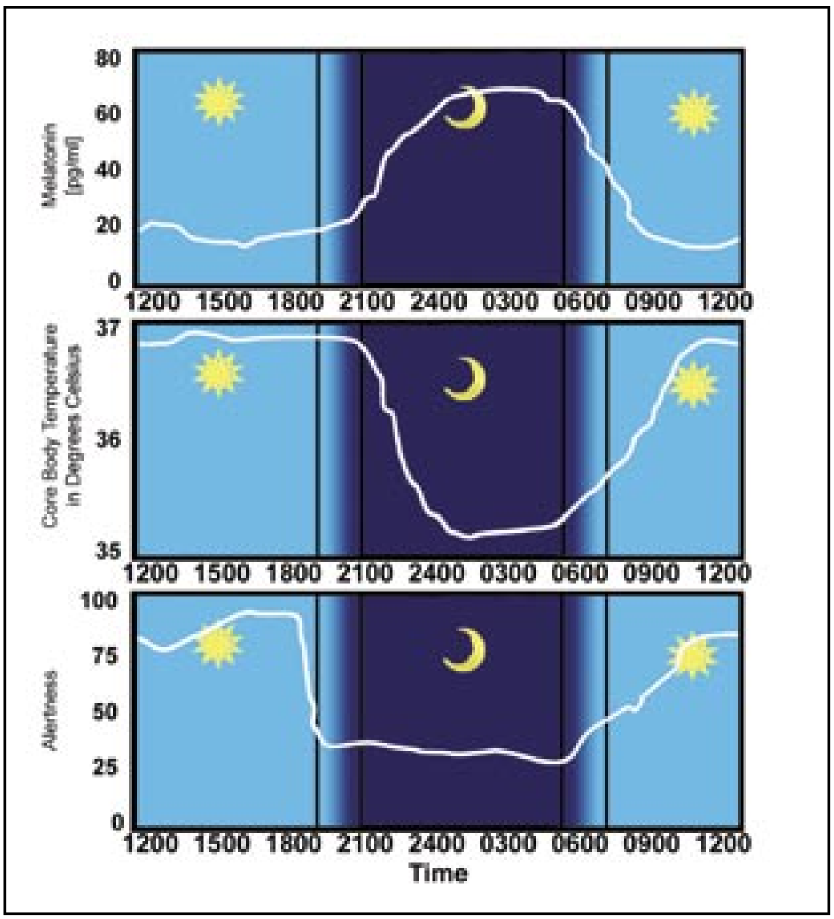

Figure 1. The Relationship Between Alertness, Core Body Temperatures, and Melatonin Levels.

Figure 1 demonstrates the relationship between alertness, core body temperatures and melatonin levels.

The bottom line is that adjusting to rotating schedules and reverse cycle is not easy. However, taking care of some of the manageable variables will lead to improved safety on the ground and in the air, better work performance, better relationships with family and friends, and better general health. ■

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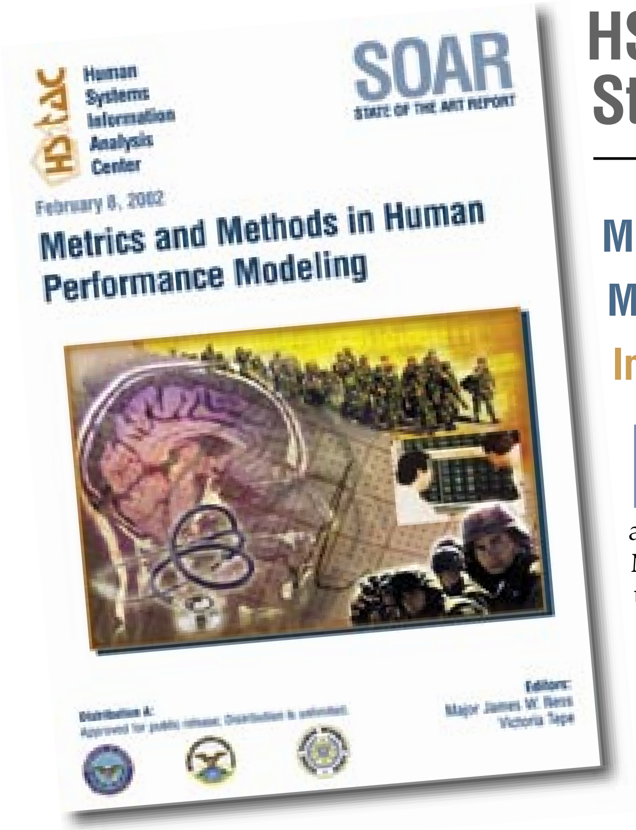

HSIAC's Forthcoming State-of-the-Art Report

Metrics and Methods in Human Performance Modeling:

Individual and Small Unit Performance

Emphasis on Army and Joint Transformation and the Objective Force has brought attention to the need for tools that will measure and predict the performance of individual combatants and small autonomous units. The U.S. Army Medical Research and Materiel Command (MRMC) has chosen HSIAC to produce a state-of-the-art report (SOAR) on Metrics and Methods of Human Performance Modeling, which will focus on individual and small unit human performance research, modeling, and simulation. The SOAR will also serve as a useful guide to researchers who seek information about currently available human performance datasets, methods, models, and simulations.

We expect this report to be available in final form early next year.

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The deadline for receipt of abstracts is October 15, 2002 for paper presentations, workshops, special interest groups, and tutorials. For more information see our information on the HSIAC web site: http://iac.dtic.mil/hsiac

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